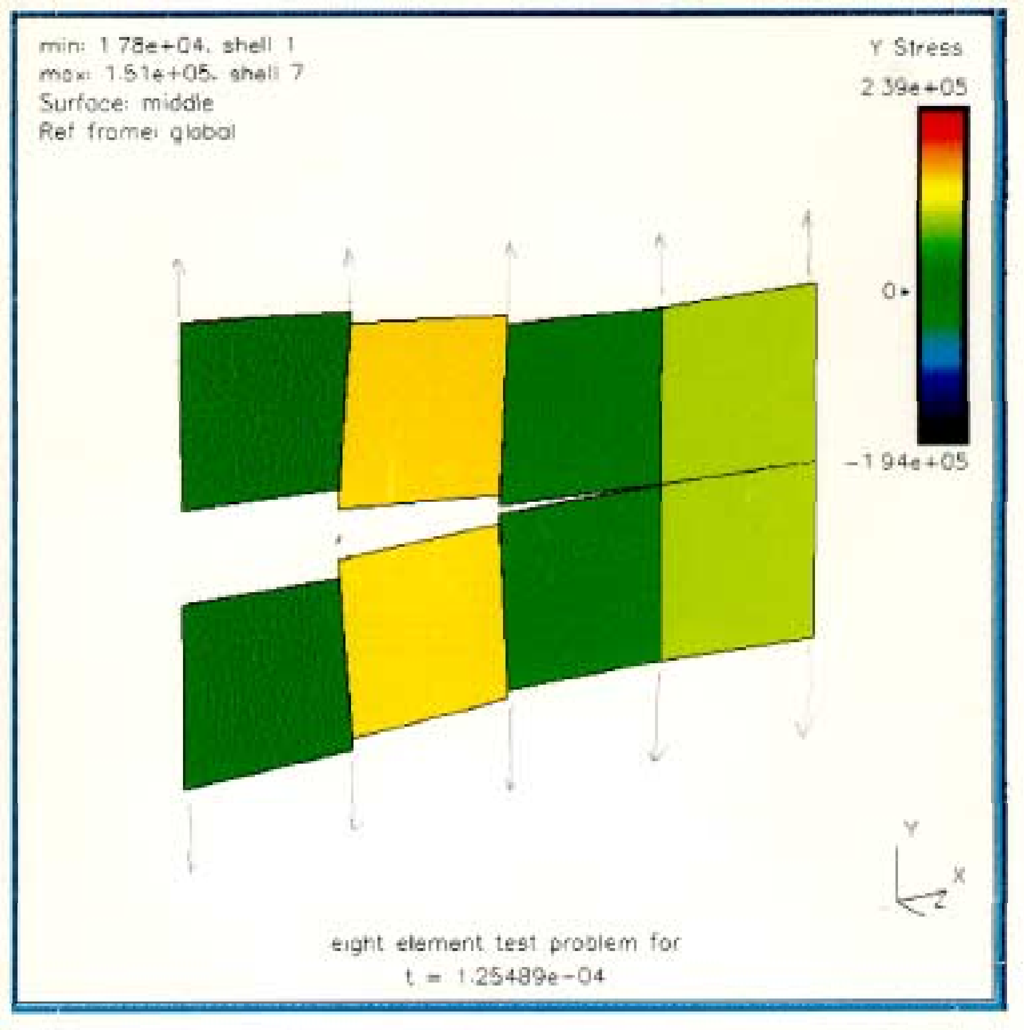
Modeling Fracture in High Explosives

Jobie Gerken

4 Years Ago

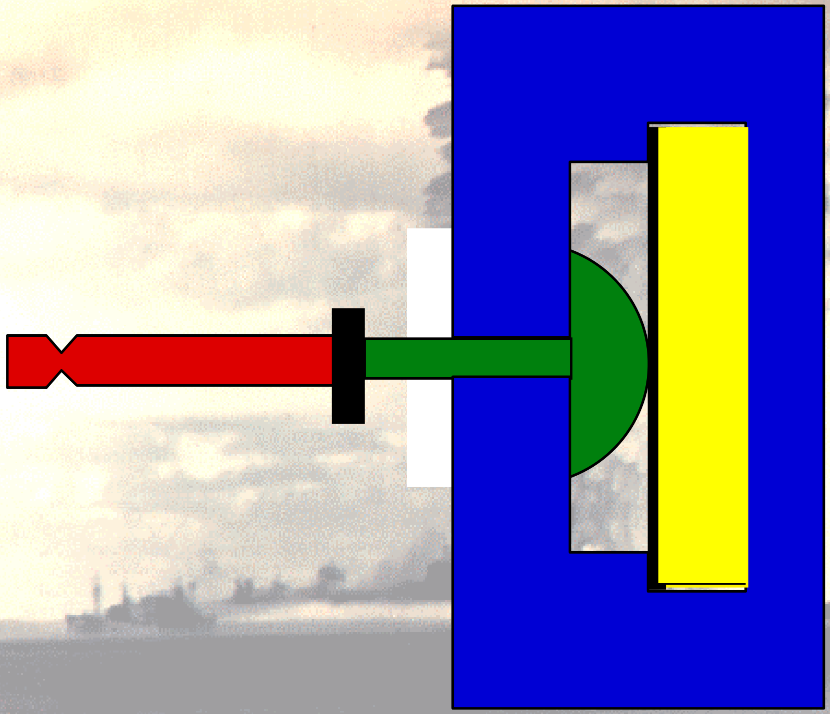


min: 1.78e+04, shell 1
max: 1.51e+05, shell 7
Surface: middle
Ref frame: global
Y Stress
2.39e+05
0
-1.94e+05
Y
X
Z
eight element test problem for
t = 1.25489e-04

If you can`t convince `em, confuse `em.

Harry S. Truman

Why Model Fracture in HE?



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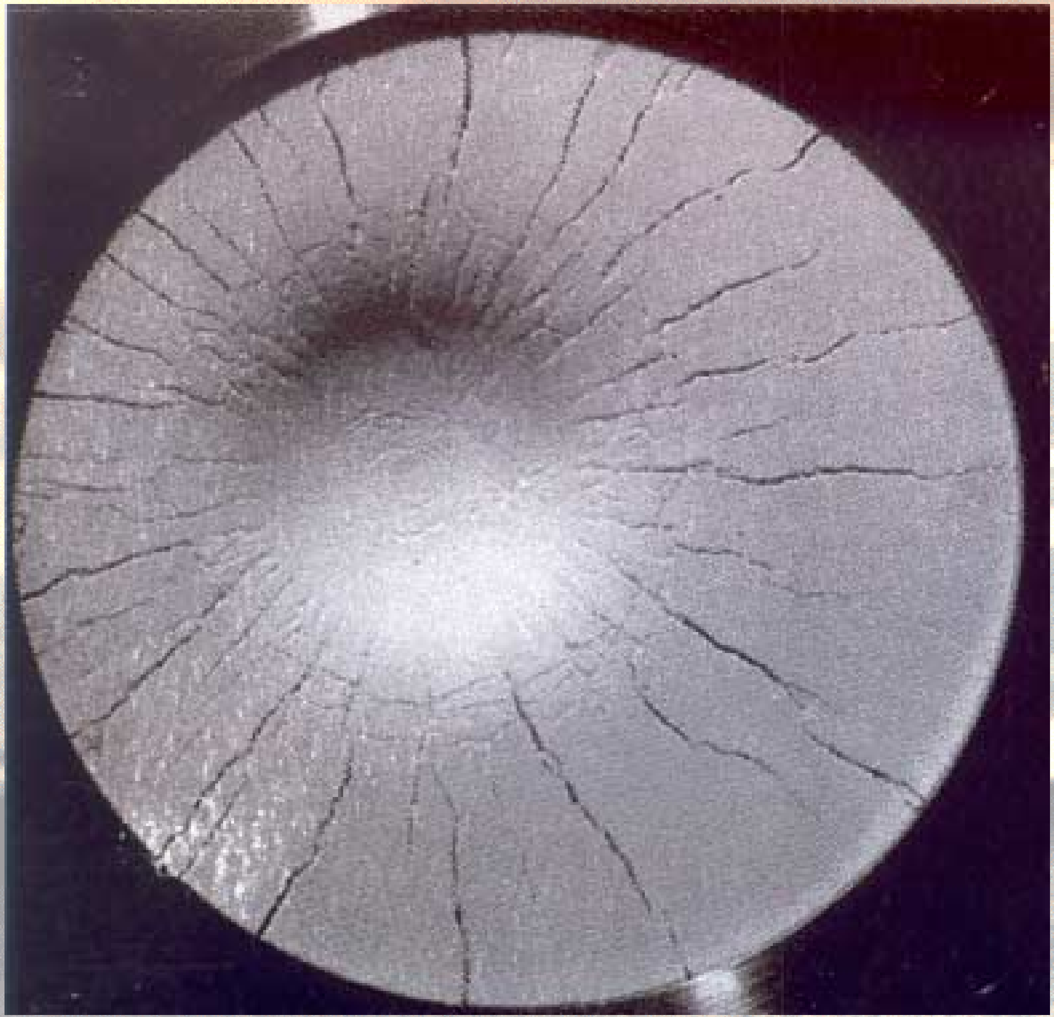

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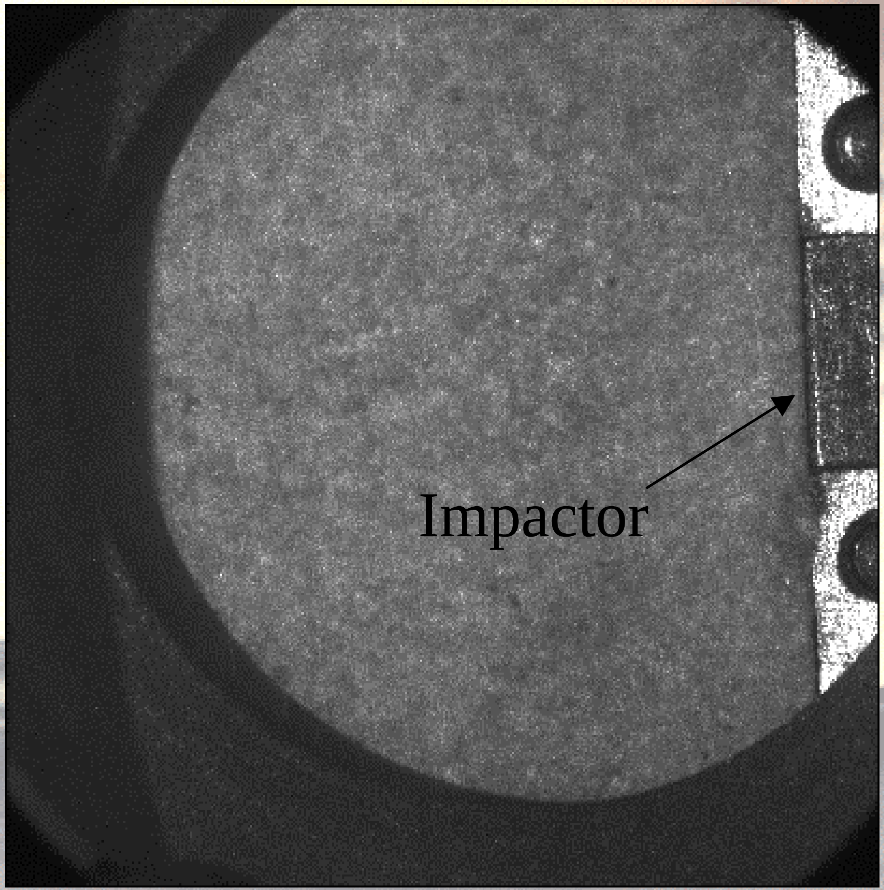

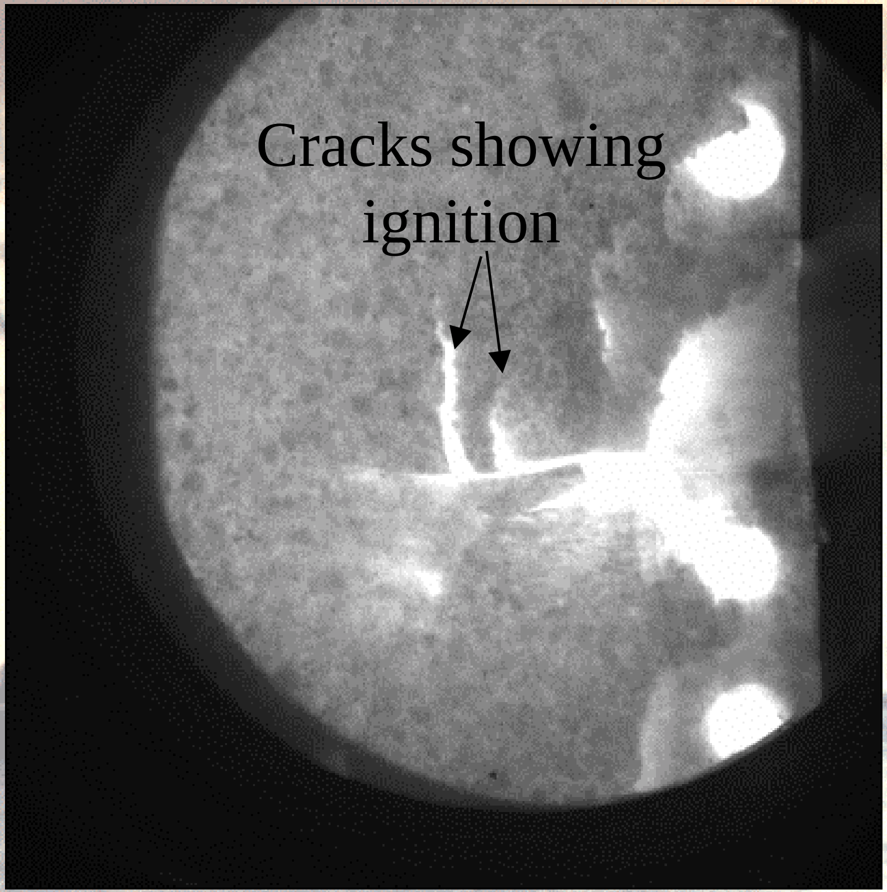

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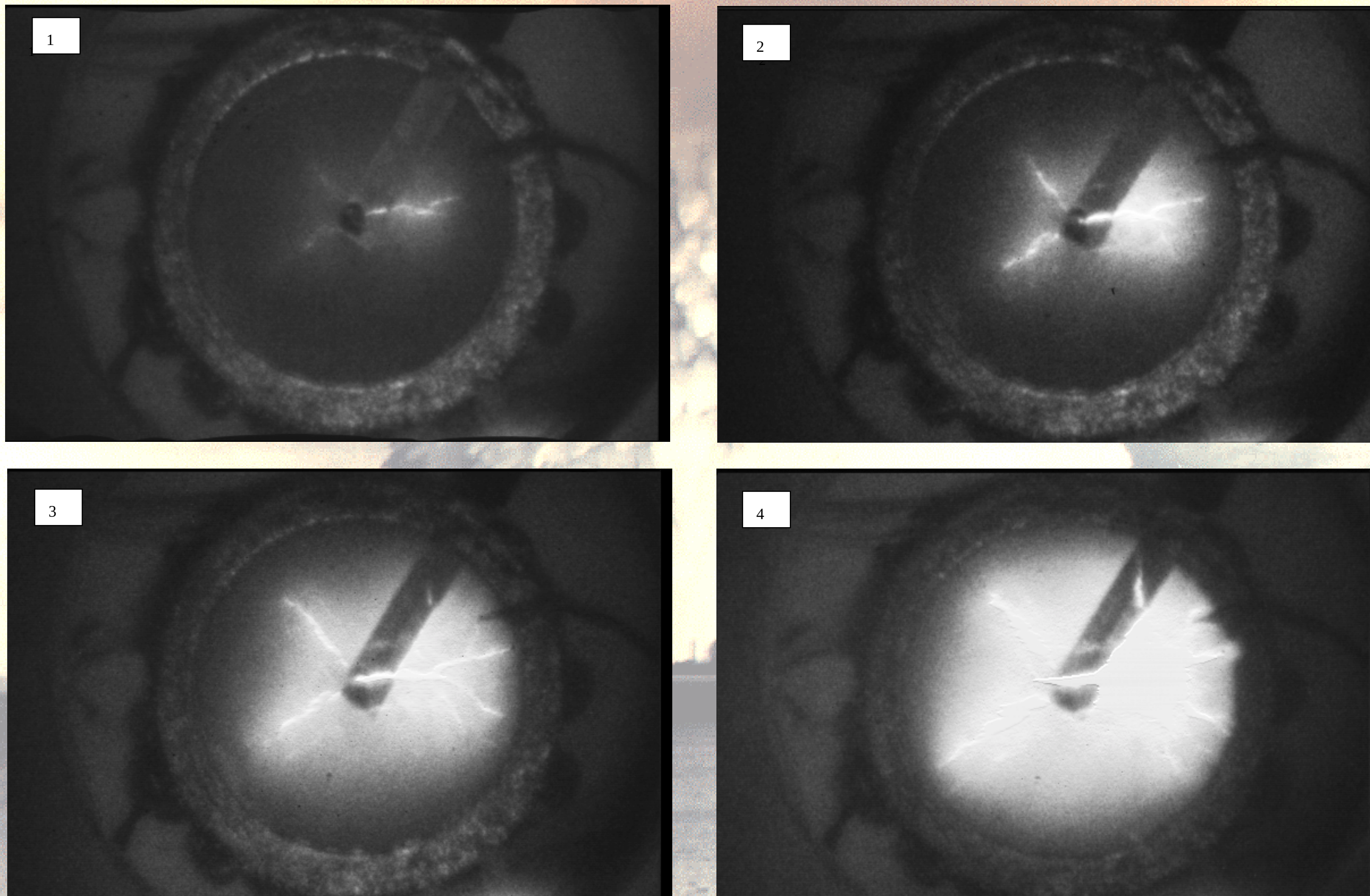


Why Model Fracture in HE?

- It does happen
- STS environments
  - If HE cracks, someone would like to know
- Abnormal environments
  - HE reaction violence could be affected by fracture

How to Model Fracture in HE?

- Computation fracture methods are lacking
  - Finite element bias
    - Most popular structural analysis method
  - No accurate methods in current FE codes
    - Damage
    - Element deletion
  - Methods in development
    - Finite Element
    - Other computational methods coupled w/ FE

How to Model Fracture in HE?

- Linear elastic fracture is well characterized
- HE is not well behaved
  - Particulate composite
  - Polymer component
  - Rate dependent
  - Not linear elastic fracture!
- Need fracture criteria for HE

Fracture Modeling

- Goodman, R. E., Taylor, R. L., Brekke, T. L., 1968 “ A Model for the Mechanics of Jointed Rock,” *Proceedings of the ASCE: Journal of the Soil Mechanics and Foundations Division*, Vol. 98, pp. 637-659.

- Liaw, B. M., Kobayashi, A. S., Emery, A. F., 1984, “Double Noding Technique for Mixed Mode Crack Propagation Studies,” *International Journal For Numerical Methods in Engineering*, Vol. 20, pp. 967-977.

- Xu, X. P., Needleman, A., 1994, “Numerical Simulations of Fast Crack Growth in Brittle Solids,” *Journal of the Mechanics and Physics of Solids*, Vol. 42, pp. 1397-1434.

- Belytschko, T., Lu, Y. Y., Gu, L., 1995, “Crack Propagation by Element-Free Galerkin Methods,” *Engineering Fracture Mechanics*, Vol. 51, pp. 295-315.

Problems with Current Methods

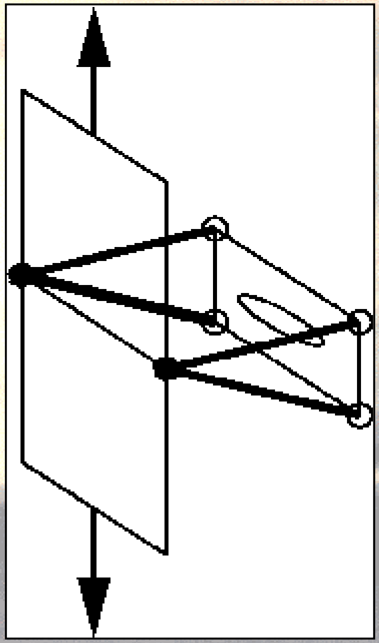
- Not applicable to structural scale models
  - Accurate when FE size ~ process zone size
  - No quick / easy fracture criteria
- No easy framework for implementation
  - Not in commercial codes
  - User written

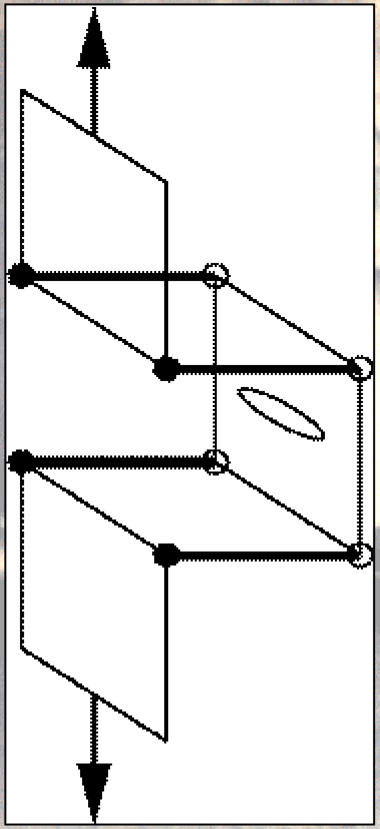
Our Fracture Method

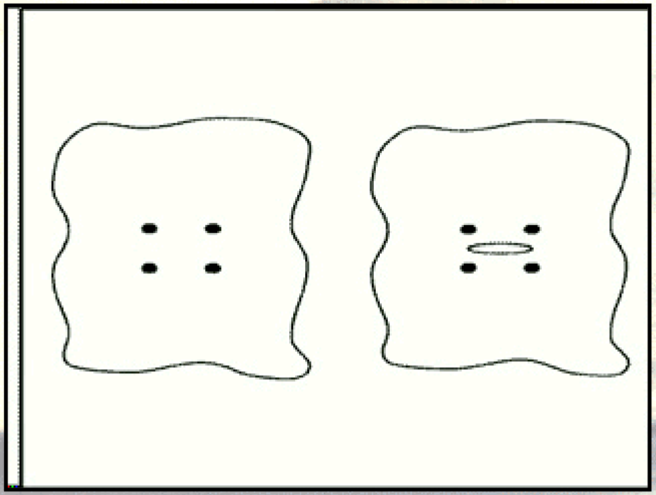
- Rigid and deformable interface models
- 2-dimensional
  - Implicit - ABAQUS/Standard
  - Explicit - DYNA3D - plates
- 3-dimensional
  - Explicit - DYNA3D - bricks

DYNA3D 2-D Model

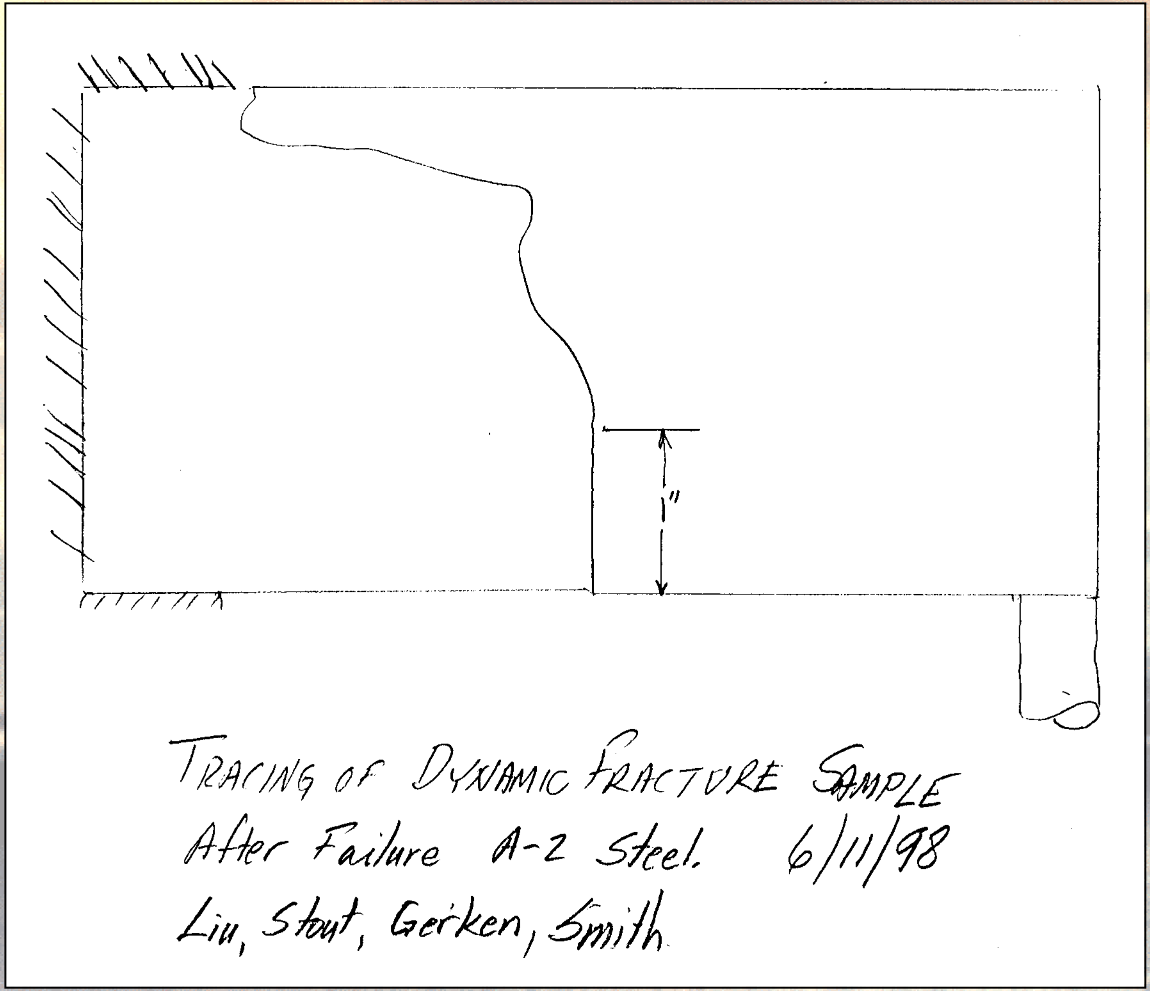
- Virtual Finite Element





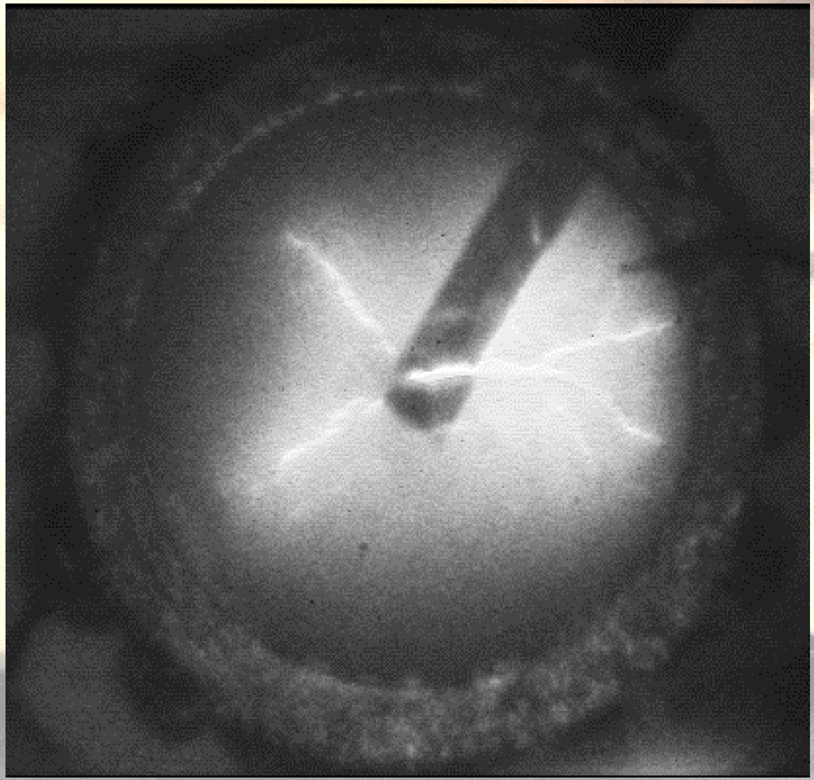


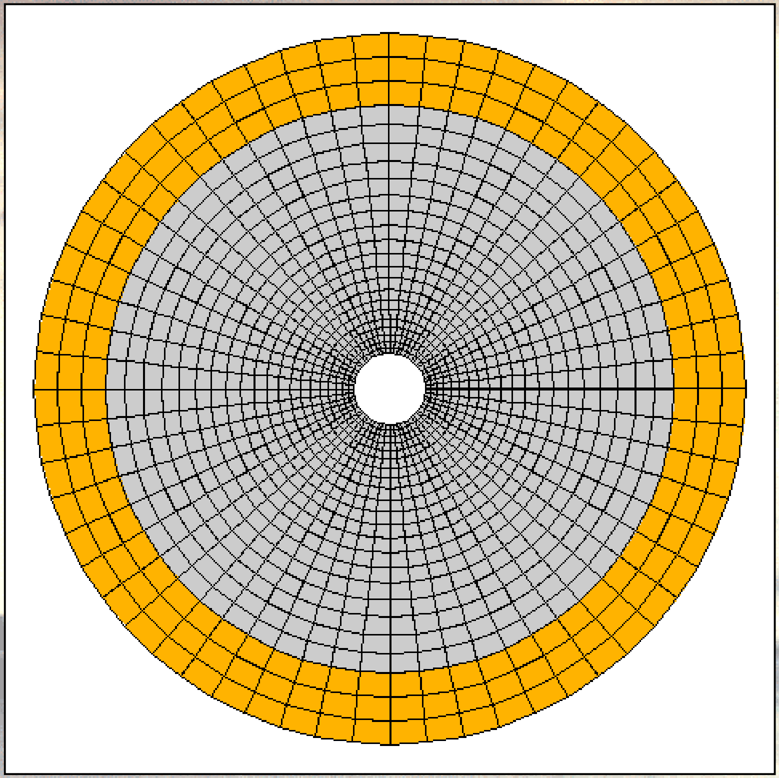
2-D Success - Steel



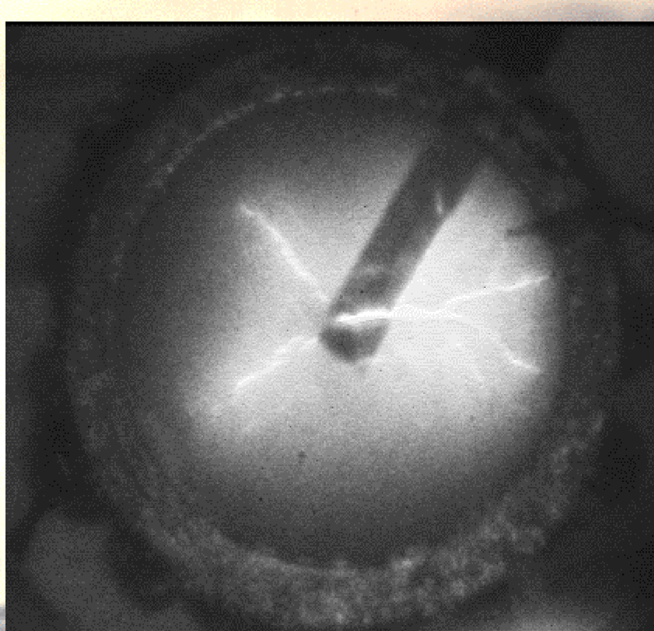
2-D Success - Steel

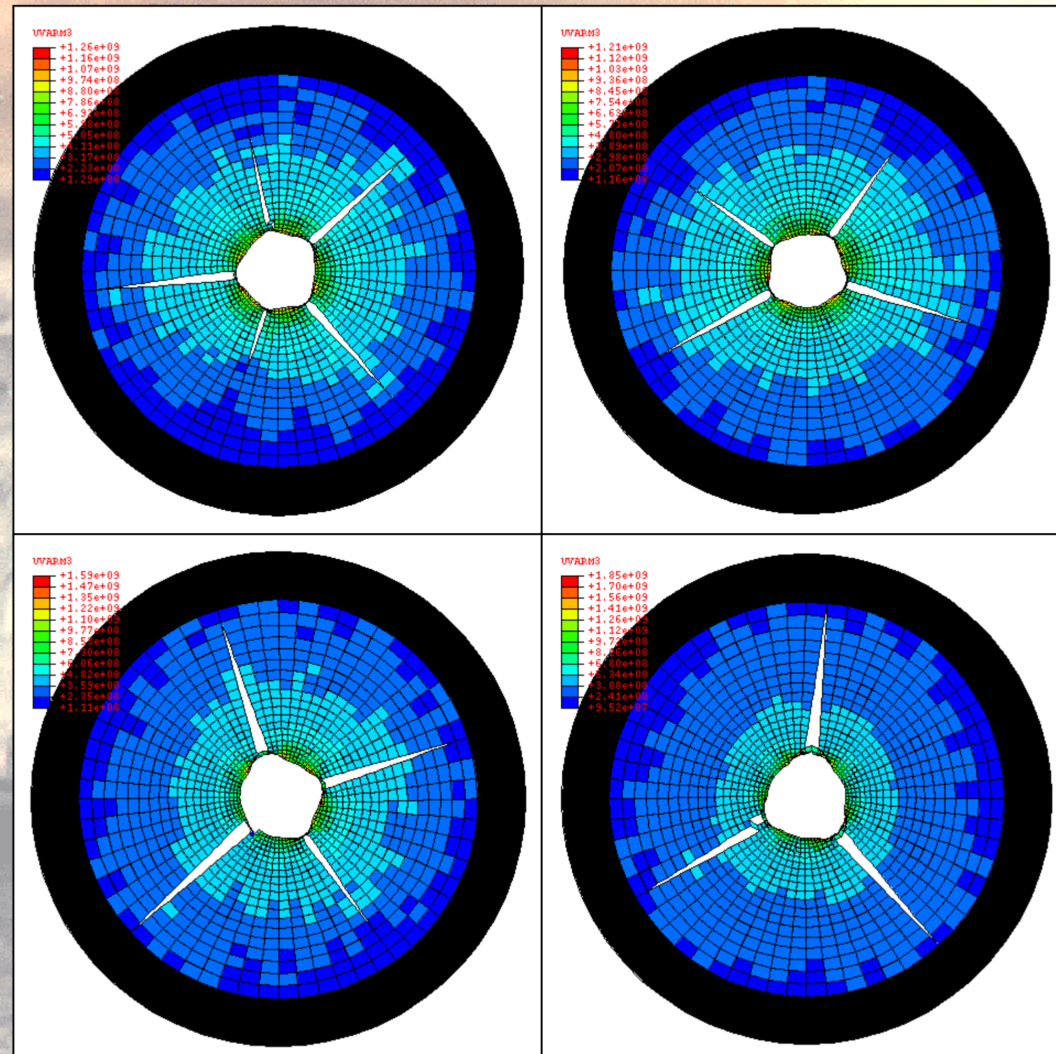
2-D Success - HE





2-D Success - HE





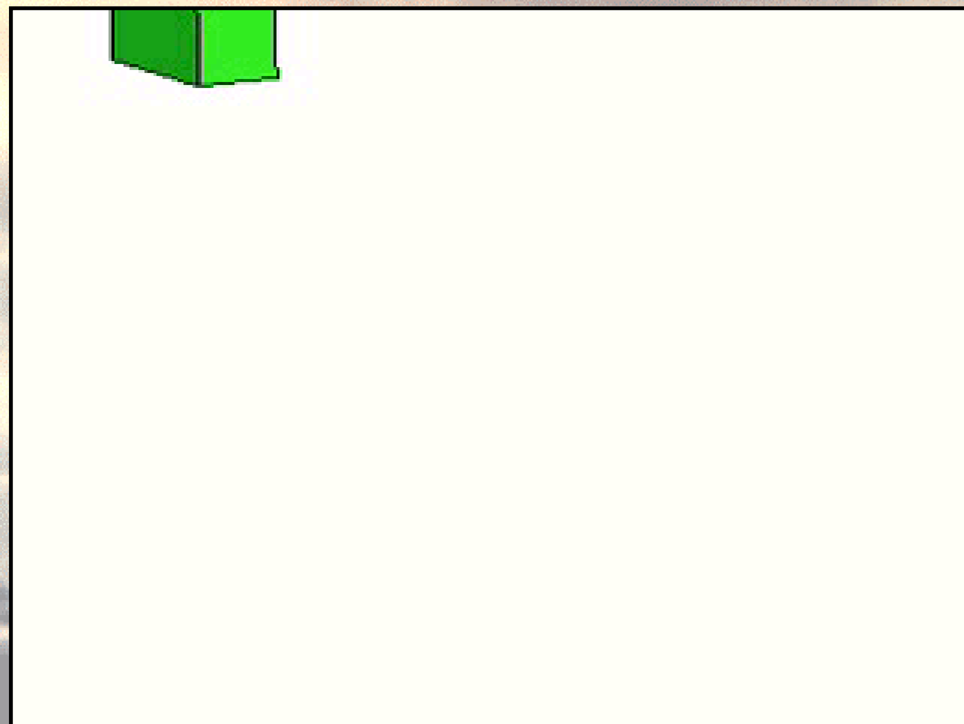
2-D Problems

- Implicit FEA is very slow
  - Fracture tends to happen on explicit time scale
- VFE would not quite work
  - Known problems we didn't want to deal with
- Contact for new crack surfaces is difficult
- Most things are not 2-D

Increase Your Dimensionality

- 3 Dimensions
  - DYNA3D
  - Each element is unique - building blocks
  - Rigid interfaces - Displacement continuity
  - Interface failure = no displacement continuity
  - Use DYNA3D auto-contact
    - New crack surface is a new contact surface

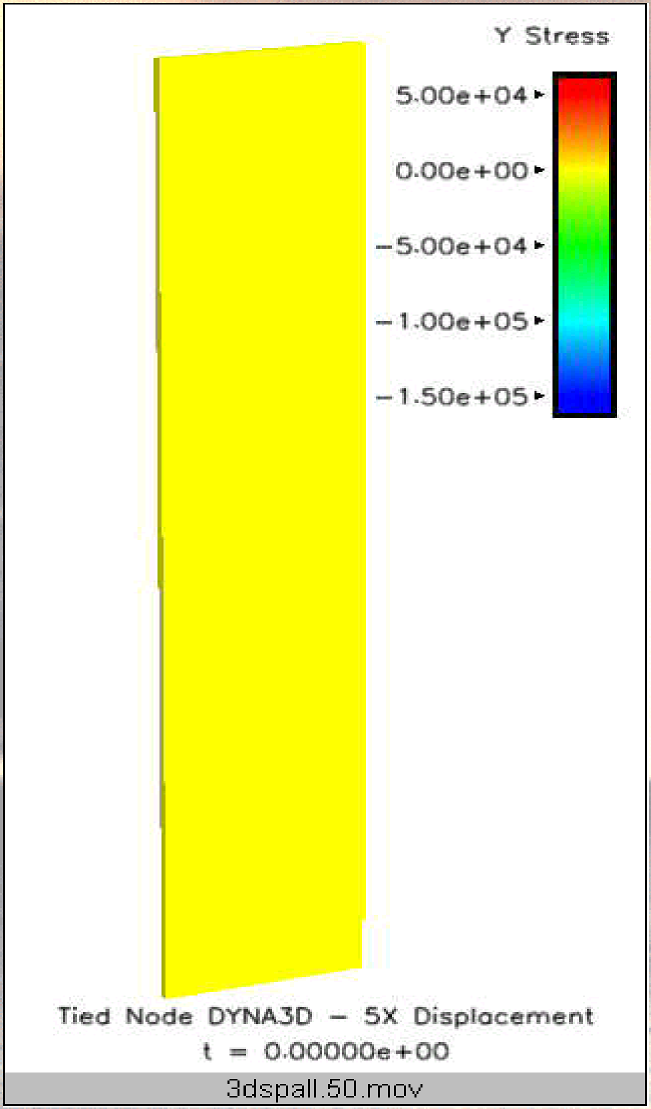
3 Dimensions



3 Dimensional Advantages

- Incorporated into DYNA3D Code
  - 1 Flag in input deck
  - 1 line of fracture parameters
- Internal to the code
  - Redefine mesh
  - Ensure displacement continuity
  - Modifies contact surface definition to include new crack surface
  - Evaluate failure
    - provides testbed for failure criteria

3-D Success? - Steel

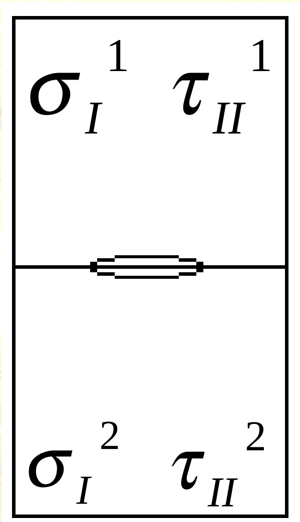


Failure Criteria

- This is the crux of the whole problem
- Fracture/failure criteria
  - Reproduce fracture/failure behavior
  - Evaluate on the local scale
  - “Normal” element sizes

Fracture Mechanics

- Small Crack at element interface

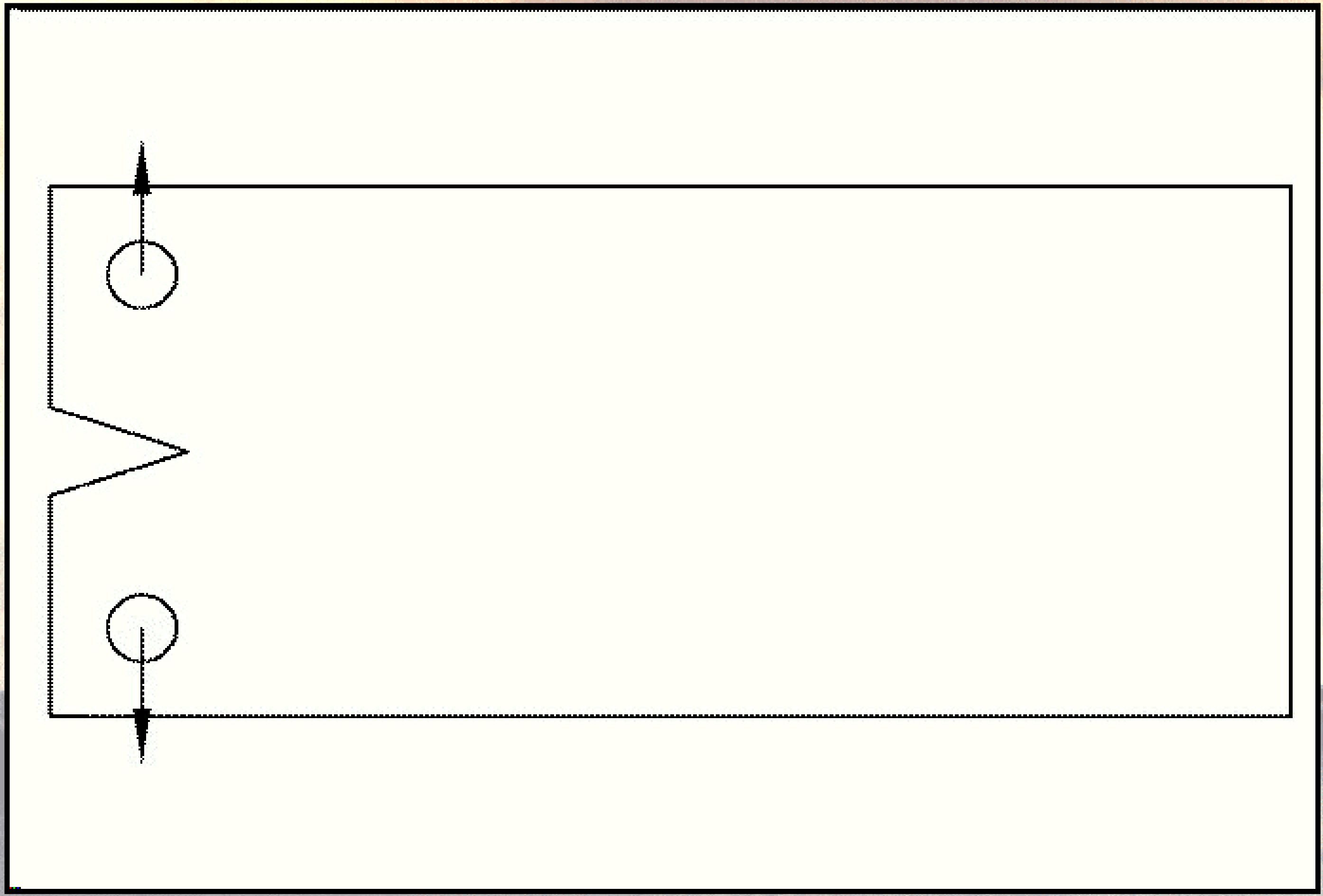


$$K_I = \sigma_I \sqrt{\pi \cdot a} \qquad K_{II} = \tau_{II} \sqrt{\pi \cdot a}$$

$$G = \frac{K_I^2 + K_{II}^2}{E}$$

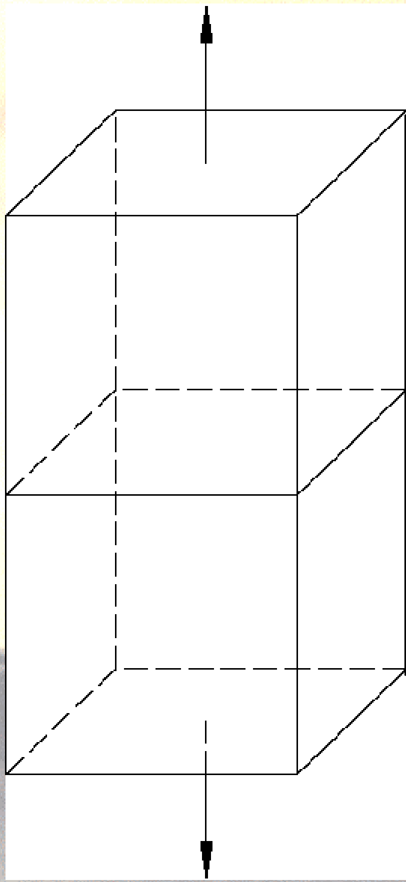
$$G = \beta (\Delta a)^\gamma + \lambda \qquad \Delta a = \left(\frac{G - \lambda}{\beta} \right)^{\frac{1}{\gamma}}$$

HE Fracture



Bridging Now

- ViscoSCRAM bridging law

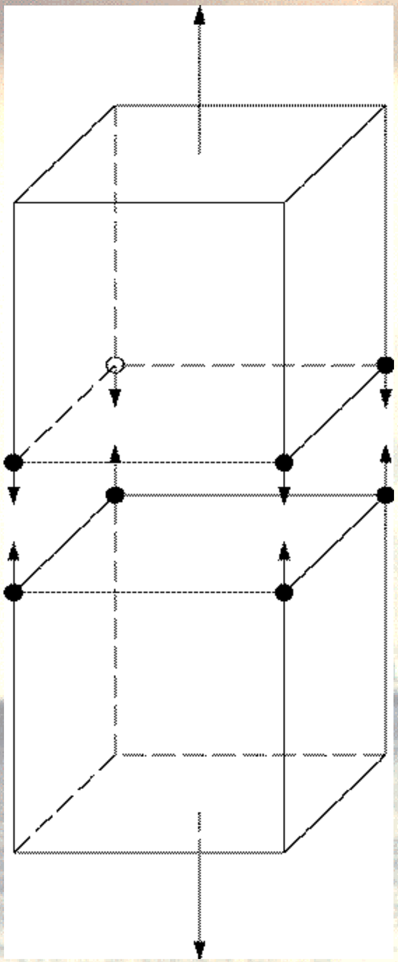


-Disp. continuity until critical stress

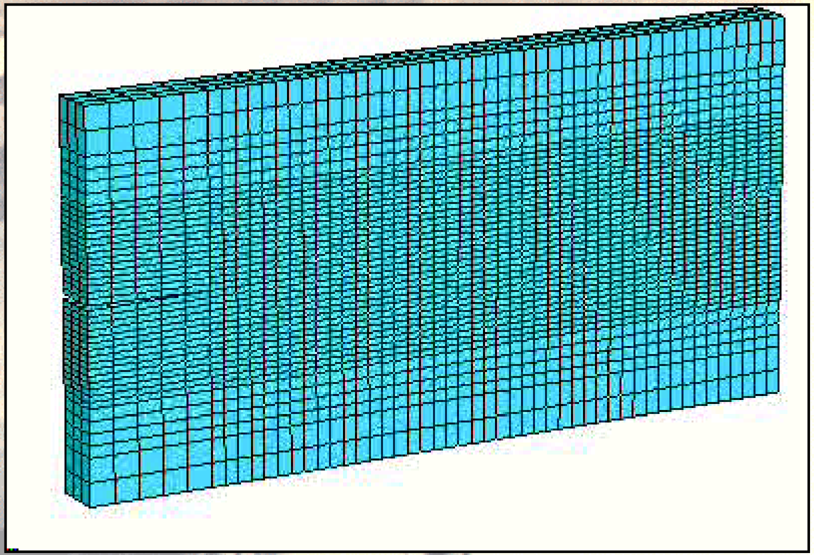
-Apply forces to nodes

- Now: $F(\sigma_{vs},A)$

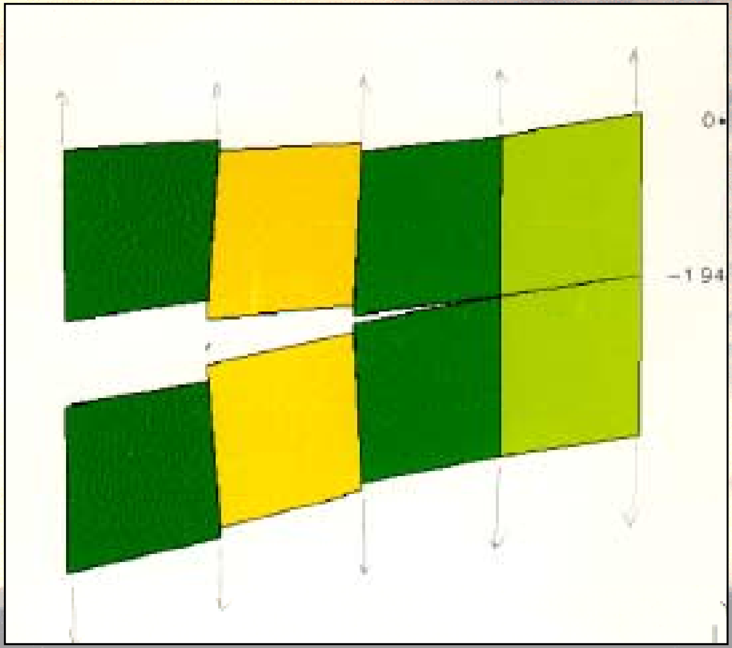
-Future: $F(\sigma_{vs},A,\delta,\dot{\delta},\varepsilon,\dot{\varepsilon},L,\ldots)$

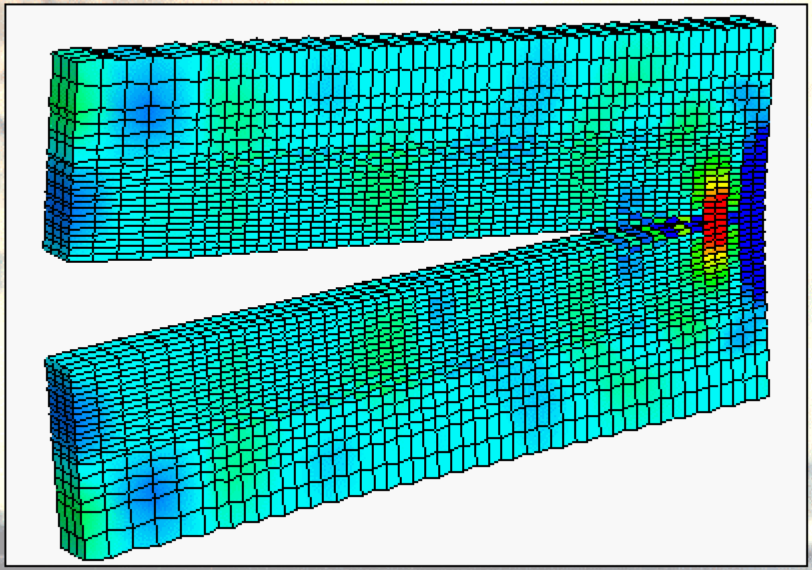


Bridging Success



4 Years of Work





The Future of HE Fracture

- Stress Bridging
- HE decomposition / gas evolution / crack face burning
- DYNA3D production release?